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9-27-2013

Physics 2710 – Example Exam I

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Recommended Citation

Peak, David, "Physics 2710 – Example Exam I" (2013). *Exams*. Paper 1.

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Please **circle the letter corresponding to the best answer.**

1. In a double slit experiment done with monochromatic (single color) laser light the *wavelength of which is greater than the slit spacing*, there

- (a) are no maxima
- (b) is exactly one maximum, in the $\theta = 0^\circ$ direction
- (c) are two maxima, at $\theta = \pm 10^\circ$
- (d) are three maxima, at angles θ that depend on the wavelength

2. A double slit interference pattern produced by monochromatic laser light has 5 bright spots. The largest value of the intensity maxima index n in the expression $d \sin(\theta) = n\lambda$ is

- (a) 1
- (b) 2
- (c) 3
- (d) 5

3. The number of photons emitted per second by an FM station with broadcast power of 10^5 W and carrier frequency of 10^8 Hz is closest to

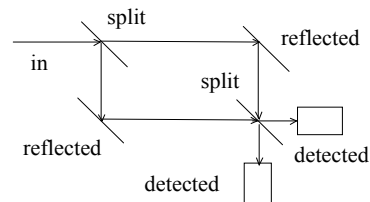
- (a) 10^{-5}
- (b) 10^5
- (c) 10^{10}
- (d) 10^{30}

4. The momentum of a photon is

- (a) h/λ
- (b) hf
- (c) $m_{\text{photon}}c$
- (d) 0

5. When done one photon at a time, the apparatus in the schematic diagram as shown to the right allows one to

- (a) determine which path the photon travels over
- (b) determine both the photon's particle and wave properties simultaneously
- (c) deduce only that a photon has particle properties
- (d) deduce only that a photon has wave properties



6. A singly ionized carbon-60 molecule, C_{60}^+ , and a proton, p^+ , both accelerate from rest through an electric potential difference of 100 V. Which *one* of the following is true? They have equal

- (a) momenta
- (b) masses
- (c) kinetic energies
- (d) de Broglie wavelengths

Questions 7-8 refer to: The total energy of a free (i.e., no force) massive particle traveling at any speed is $E = \sqrt{(pc)^2 + (mc^2)^2}$.

7. If the particle's speed is $\ll c$, E is approximately

- (a) $pc + mc^2$
- (b) $mc^2 + \frac{(pc)^2}{2}$
- (c) $1 + \frac{(pc)^2}{mc^2}$
- (d) $mc^2 + \frac{(pc)^2}{2mc^2}$

8. If the particle's speed is close to c , E is approximately

- (a) $(pc)^2$
- (b) mc^2
- (c) $\frac{(pc)^2}{mc^2}$
- (d) $pc + \frac{(mc^2)^2}{2pc}$

9. The operator $i\hbar\partial/\partial t$ operating on a quantum wavefunction is used to "measure" which quantity?

- (a) energy
- (b) energy squared
- (c) momentum
- (d) momentum squared

10. The expression $\exp(i\theta) = \cos(\theta) + i\sin(\theta)$ is known as

- (a) Maxwell's formula
- (b) Einstein's formula
- (c) Schrödinger's formula
- (d) Euler's formula

11. An electron trapped inside a nucleus of diameter equal to 10^{-6} nm would have a kinetic energy on the order of

- (a) 10 eV
- (b) 1 MeV
- (c) 100 MeV
- (d) 100 GeV

Questions 12-14 refer to: A photon is trapped in a 1D cavity of length L with perfect reflecting ends. The photon wavelength equals $2L/n$, where n is a positive integer.

12. The average value of the photon energy measured many times starting in the state n is

- (a) $(\pi\hbar c/L) \cdot n^2$
- (b) $\frac{(\pi\hbar c/L)}{n^2}$
- (c) $(\pi\hbar c/L) \cdot n$
- (d) 0

13. The standard deviation of the photon energy measured many times starting in the state n is

- (a) $(\pi\hbar/L) \cdot n^2$
- (b) $\frac{(\pi\hbar/L)}{n^2}$
- (c) $(\pi\hbar/L) \cdot n$
- (d) 0

14. Suppose the color of a photon in the $n=1$ state is red. How many other different color visible light photon states are allowed in the cavity?

- (a) 0
- (b) 1
- (c) 2
- (d) 3

Questions 15-20 refer to: An electron is trapped in a 1D infinite square well between $x=0$ and $x=L=0.2$ nm (where $U=0$). Its wavefunction is $\Psi = \Psi_{\max} \sin(n\pi x/L) \exp(-iE_n t/\hbar)$. Assume that Ψ_{\max} is a positive real number and the ground state energy is 10 eV.

15. Ψ_{\max} is

- (a) $5 \cdot n \text{ nm}^{-1}$
- (b) $3.16 \text{ nm}^{-1/2}$
- (c) $0.2 \cdot n \text{ nm}$
- (d) 1

16. The average value of the electron's position, $\langle x \rangle$, is

- (a) 0.1 nm
- (b) $0.2 \text{ nm}/n$
- (c) 0.2 nm
- (d) 0

17. If the electron is in the $n = 2$ state, the average value of its total energy (kinetic + potential), $\langle E \rangle$, is

- (a) 0
- (b) 10 eV
- (c) 20 eV
- (d) 40 eV

18. If the electron is in the $n = 2$ state, the average value of its kinetic energy, $\langle p^2 c^2 \rangle / 2mc^2$, is

- (a) 0
- (b) 10 eV
- (c) 20 eV
- (d) 40 eV

19. If the electron is in the $n = 2$ state, the probability of finding it is

- (a) zero at $x = 0$ and 0.2 nm only
- (b) zero at $x = 0, 0.1$ nm, and 0.2 nm only
- (c) zero at $x = 0.1$ nm only
- (d) the same at all values of x inside the well

20. The electron, initially in the *second excited state*, somehow undergoes a transition to the ground state by emitting a photon. The photon energy is

- (a) 10 eV
- (b) 30 eV
- (c) 50 eV
- (d) 80 eV

21. The wavefunction of a free particle is a plane wave with an exactly known momentum in the x -direction. According to the Heisenberg Uncertainty Principle the uncertainty in the particle's x -position is

- (a) about three wavelengths
- (b) infinite
- (c) hc divided by its kinetic energy
- (d) zero

Questions 22-24 refer to: An electron moving along the x -axis experiences a *finite well* potential energy that is zero for $0 < x < 0.5$ nm and +17 eV otherwise. There are four bound states within the well with energies (in eV) 1.07, 4.22, 9.26, and 15.47, corresponding to the quantum numbers $n = 1, 2, 3$, and 4, respectively. The energies (in eV) of the bound states with the same quantum numbers in a 1D *infinite square well* of the same length are 1.50, 6.00, 13.50, and 24.00.

22. Let $P_n = \int_0^{0.5 \text{ nm}} |\Psi_n|^2 dx$ be the probability of finding the electron *inside* the well if it is in the state n . Which *one* of the following is true?

- (a) $P_1 > P_2 > P_3 > P_4$
- (b) $P_4 > P_3 > P_2 > P_1$
- (c) $P_1 = P_2 = P_3 = P_4 = 1$
- (d) $P_1 = P_2 = P_3 = P_4 = 0$

23. A transition between 2 bound states ($n_{initial} \rightarrow n_{final}$) is associated with a photon carrying energy equal to 3.15 eV. Which *one* of the following is possible?
- (a) $1 \rightarrow 2$
 - (b) $3 \rightarrow 2$
 - (c) $2 \rightarrow 4$
 - (d) $4 \rightarrow 1$
24. An electron in a plane wave state traveling from $x < 0$ to $x > 0$ will pass through the well with *no reflection* if its total energy (kinetic + potential) equals
- (a) 1.50 eV
 - (b) 6.00 eV
 - (c) 13.50 eV
 - (d) 24.00 eV
25. An electron in a plane wave state, with initial kinetic energy equal to E_0 , traveling from $x < 0$ to $x > 0$ encounters a potential energy that is $U_0 > 0$ for $0 < x < L$ and zero otherwise. If $E_0 < U_0$ the probability of finding the electron at $x > L$ is T . Which *one* of the following is true?
- (a) $T = 0$
 - (b) $T = 1$ and the electron's kinetic energy is less than E_0
 - (c) $T < 1$ and the electron's kinetic energy is less than E_0
 - (d) $T < 1$ and the electron's kinetic energy is equal to E_0